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Keck Interferometer Update

Mark Colavita, JPL

Origins Subcommittee Meeting

July 12, 2001

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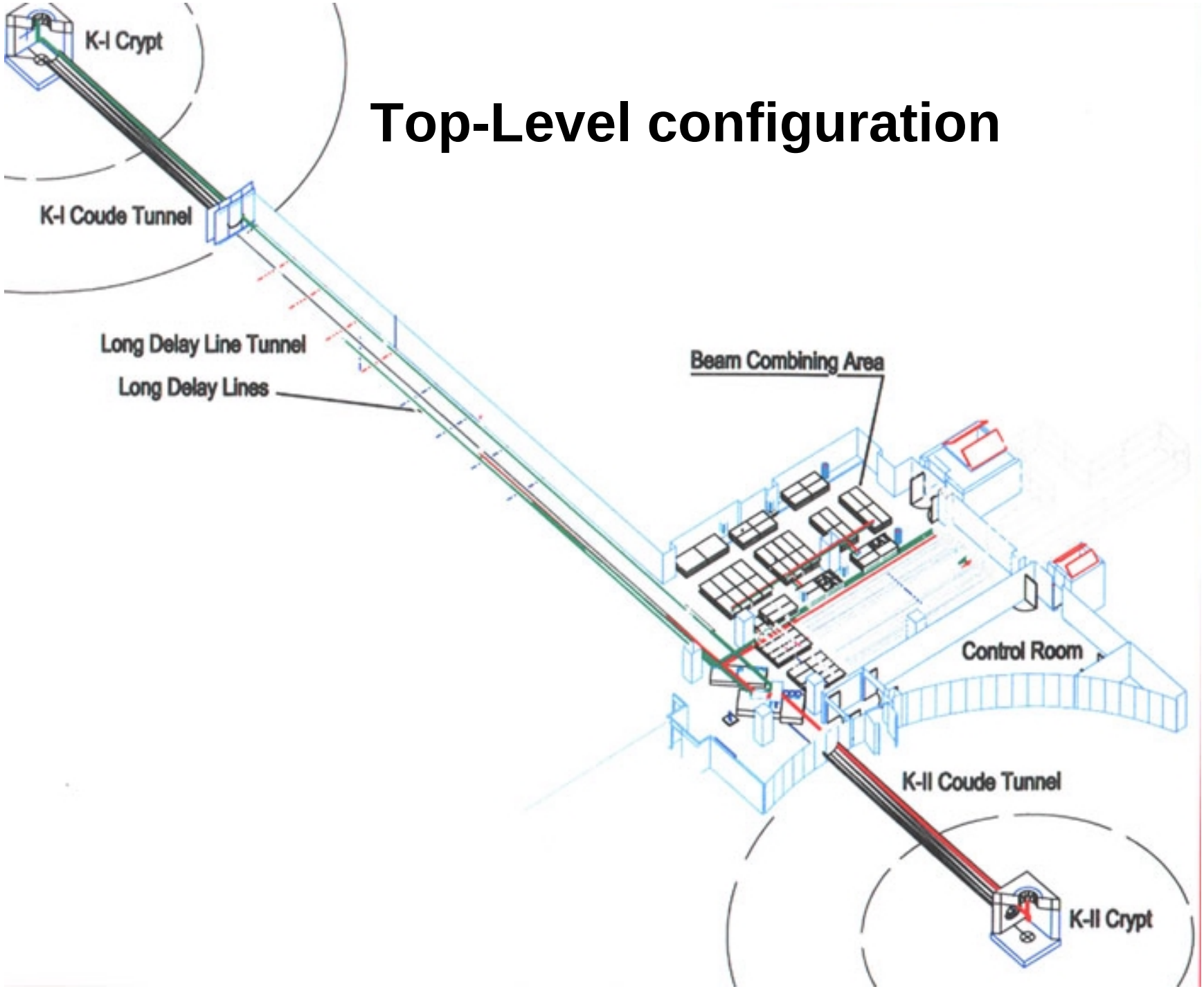
Keck Interferometer Fact Sheet

- Organizations
  - Funding from NASA through Navigator Program
  - JPL
  - CARA / W. M. Keck Observatory
  - Interferometry Science Center
- Science
  - Characterization of exo-zodiacal emission at 10 λm around nearby stars
  - Spectroscopic detection of warm, giant planets
  - Astrometric detection of Uranus-mass planets
  - Imaging of protoplanetary disks, AGN. etc.
- Instrument
  - Two 10-m Keck telescopes, 85 m baseline
  - Four 1.8-m outrigger telescopes, 30-135 m baselines
  - Adaptive optics on both 10 m telescopes
  - Infrared fringe detection and tracking
  - Instrumentation
    - » Two-way beam combiners at 1.5 - 2.4 λm
    - » Nulling combiner at 10 λm
    - » Multi-way imaging combiner at 1.6 - 5 λm

Top-Level configuration



Basement Infrastructure Installation

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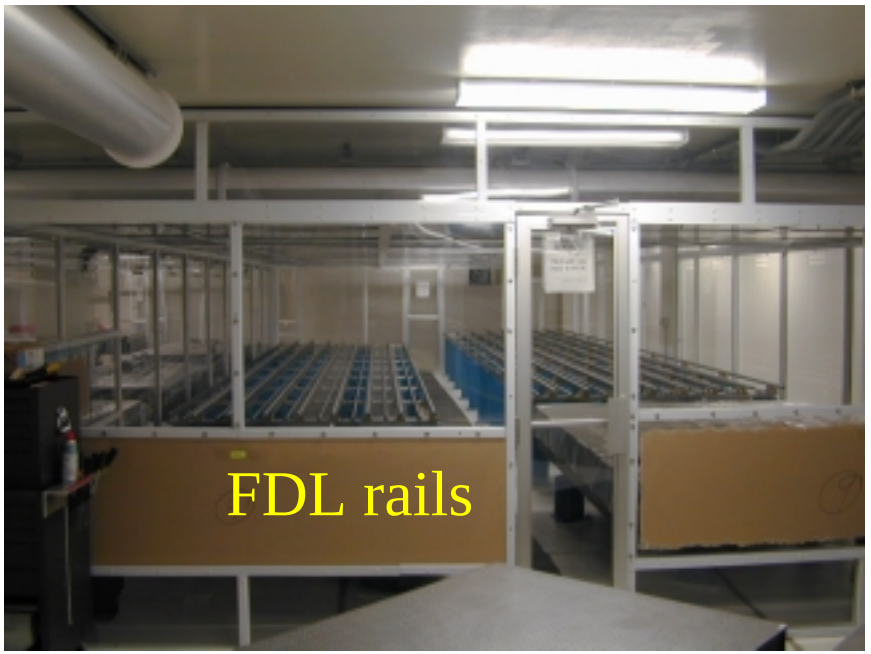
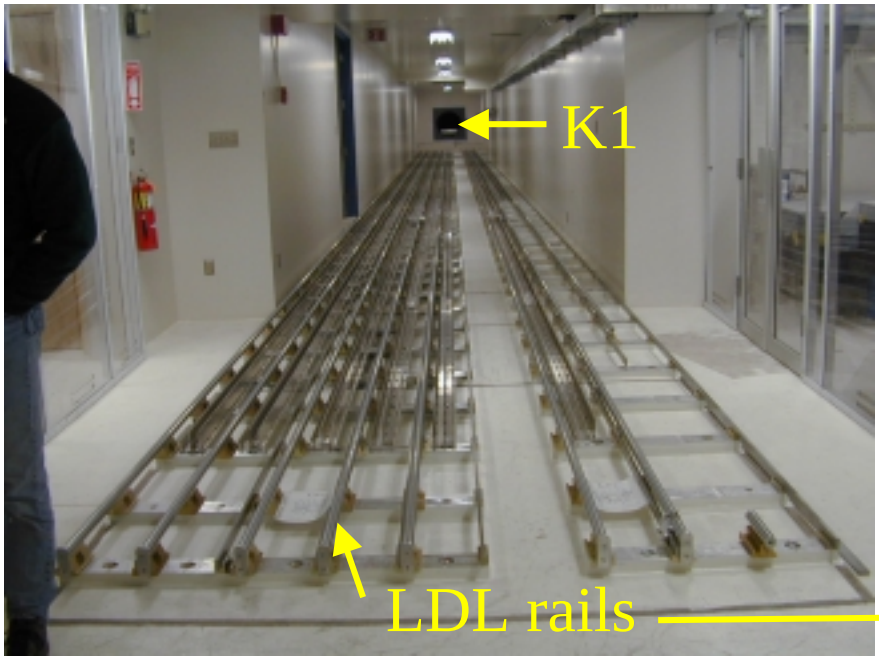
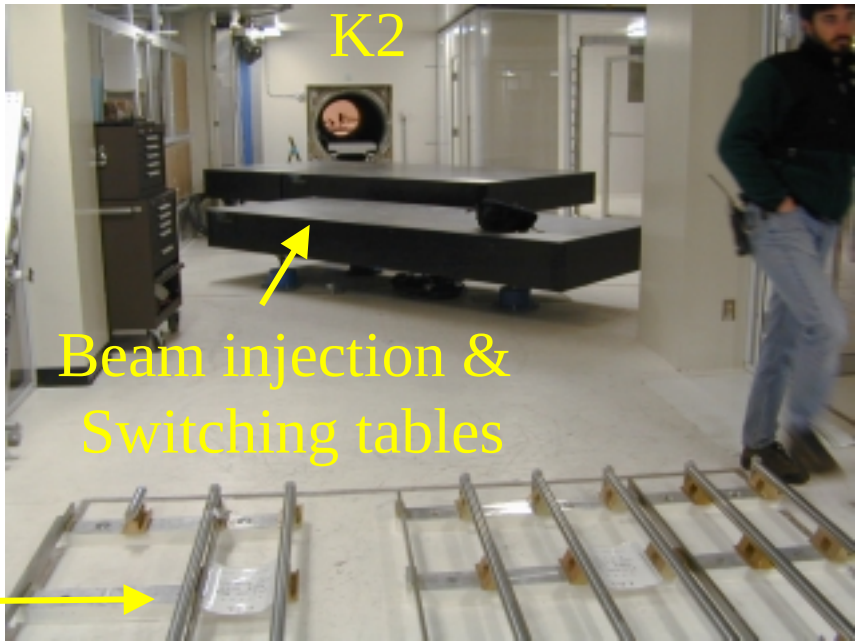




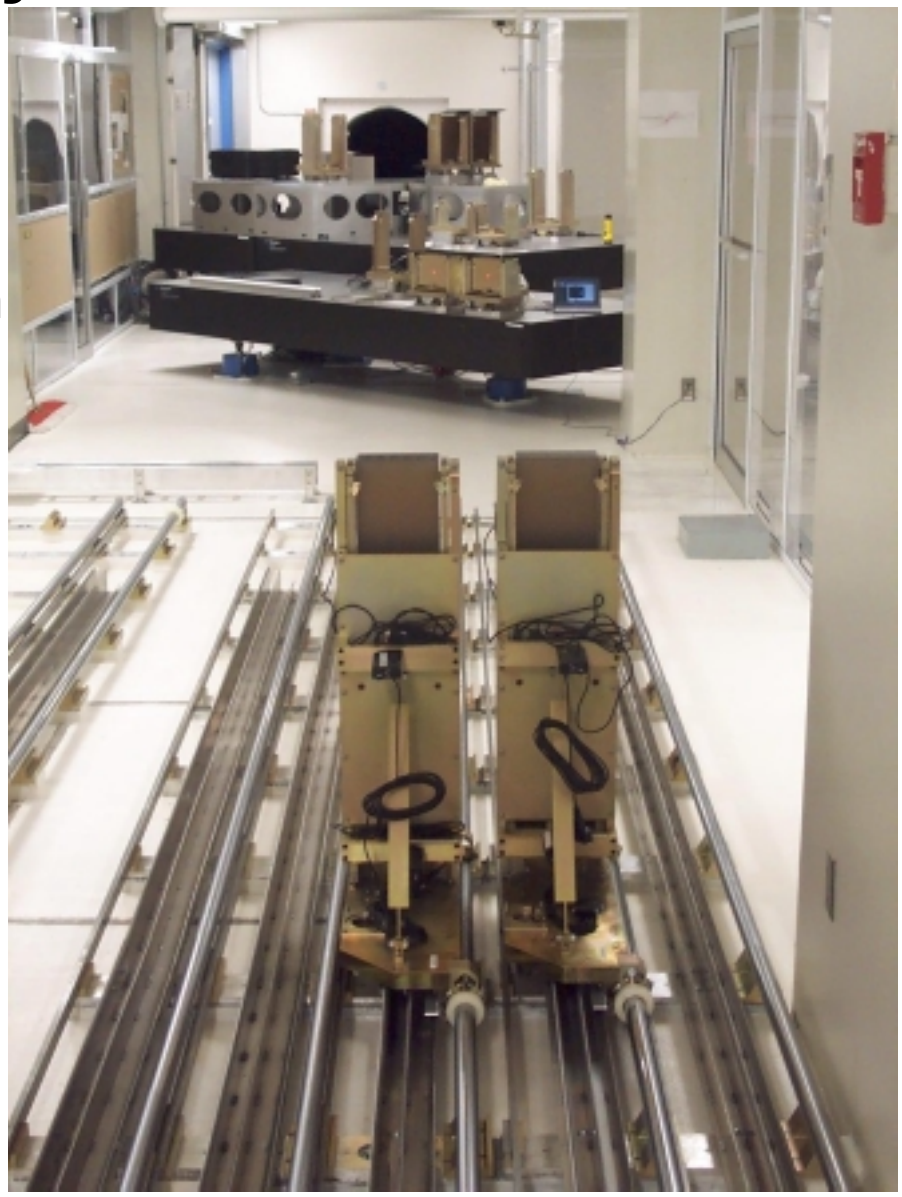


Keck AO for Interferometer

- K1 1st light a success on Dec. 12
  - Engineering on 12/12-14/00 & 1/8,11,12/01
- January engineering run focused on testing K1 EPICS upgrade to Wavefront Controller
- K1 & K2 AO systems & telescopes run from K1 control room on 1/12 & 2/1 pointing at same objects
- Motorized beamsplitters installed on AO benches to feed DSM. DSMs aligned to AO benches
- Offloading loop from KAT to AO system in testing phase
- Observing assistants now operate K2 AO with AO expert support

Long Delay Lines

- LDL sleds move along coude tunnel in basement
  - ‘Move and clamp’ operation to provide delays up to 170 m
  - Stationary during an observation



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Fast Delay Lines

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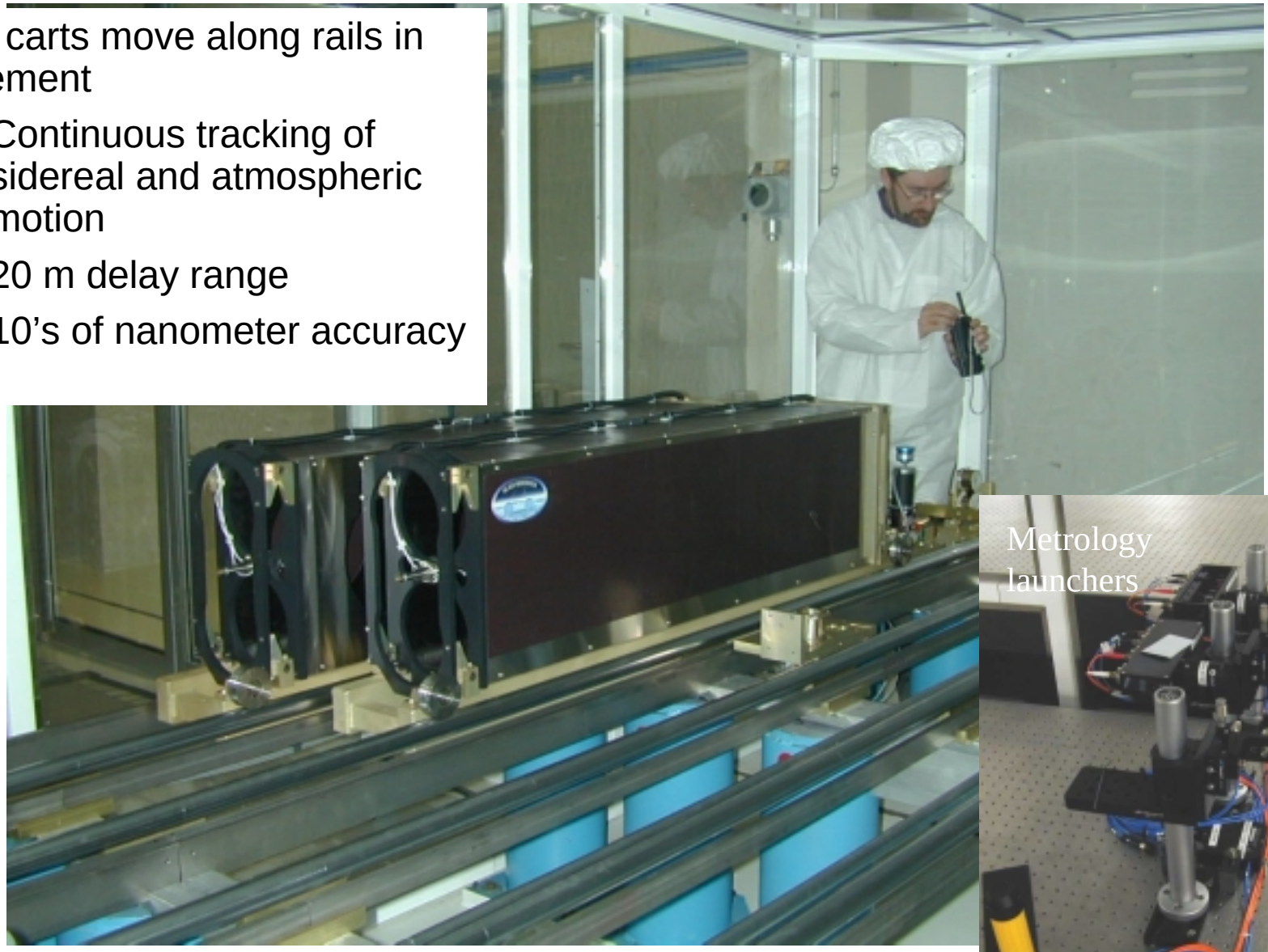
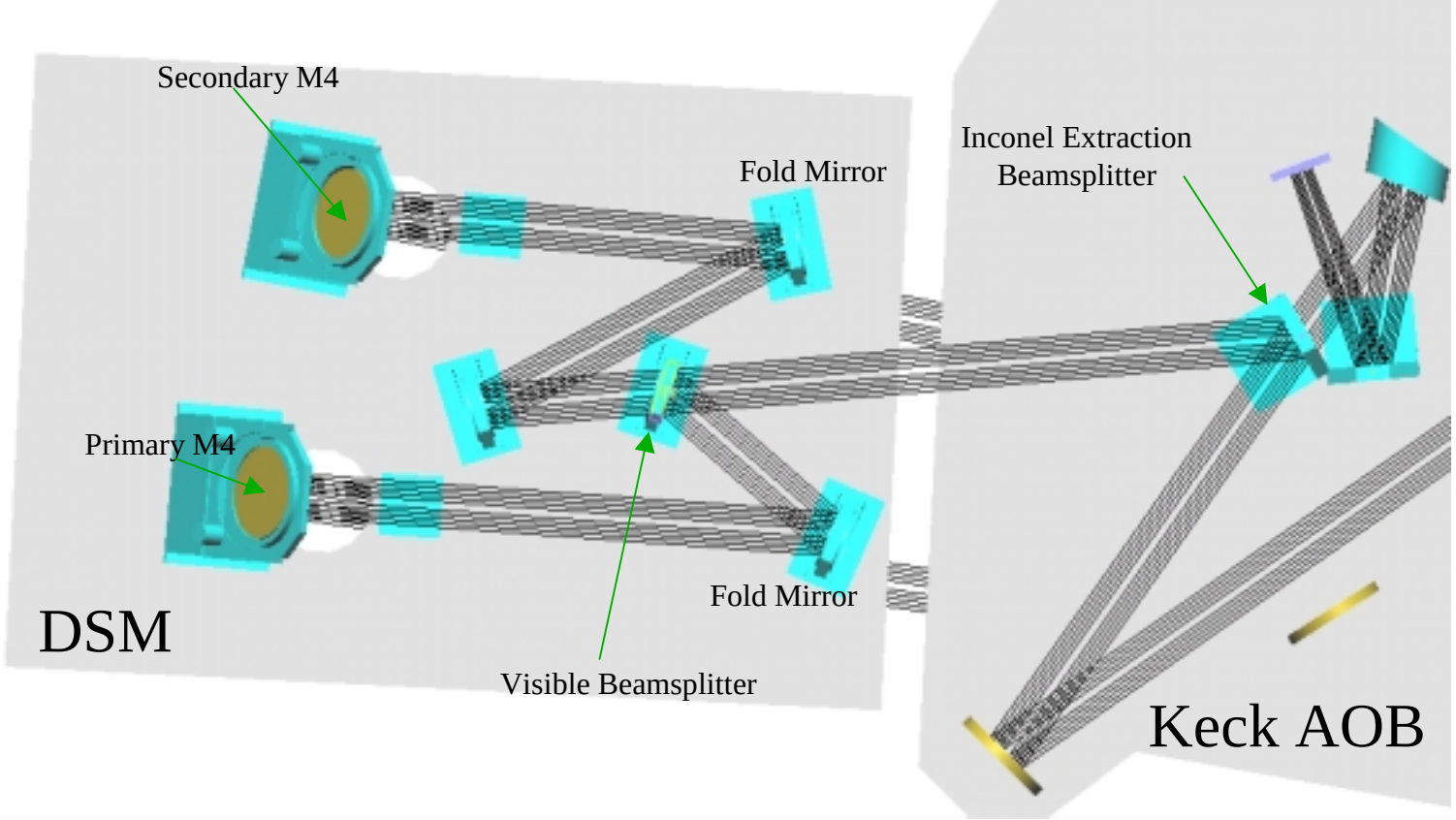
- FDL carts move along rails in basement
  - Continuous tracking of sidereal and atmospheric motion
  - 20 m delay range
  - 10's of nanometer accuracy



Dual star module

- Extracts light from collimated output after AO system deformable mirror and feeds to coude system
  - DSM for Keck 1 and Keck 2 installed on handling cart, aligned
  - Primary path optics installed for first fringes



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Optical Infrastructure

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- Beam transport optics
- Switchyard optics for 2-element operation
  - FATCAT dichroics and mounts
  - KAT dichroics and mounts
  - Auto-alignment camera and detector
  - Fold mounts
  - FTS corner cubes
  - Beam compressors
- Fringe tracker stimulus and white-light source

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FATCAT (Fringe tracker)

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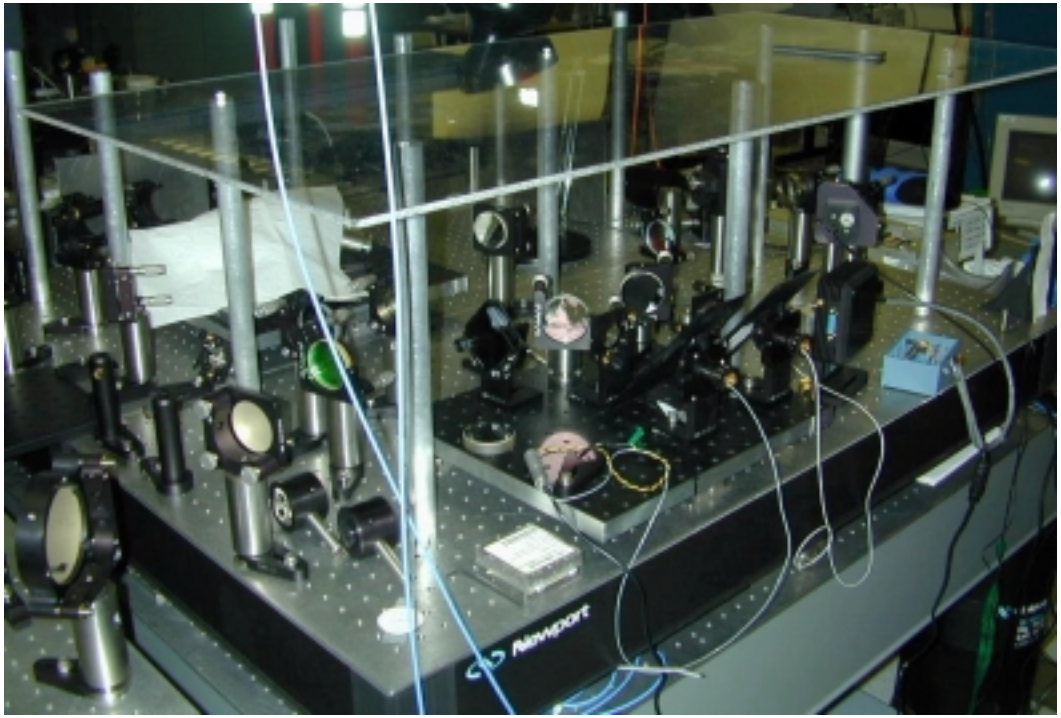
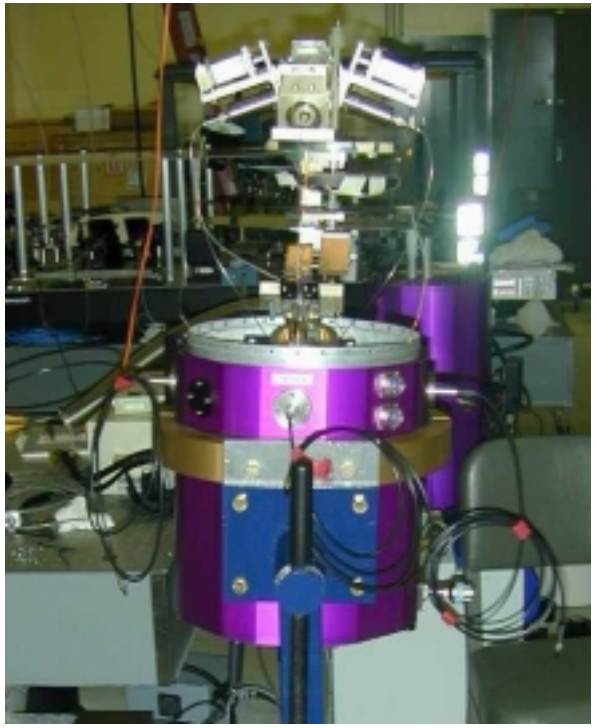
- Two-way Michelson beam combiner
- Combined light is spatially filtered via a single-mode fluoride glass fiber which directly feeds dewar
- K-band fringe tracking
- FATCAT dewar, optics, and first-fringe software installed and aligned on mountain





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KAT (Angler tracker)

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- Multiplexes beam from 2 to 6 telescopes to track relative tilts
- KAT dewar, optics, and software installed and aligned on mountain

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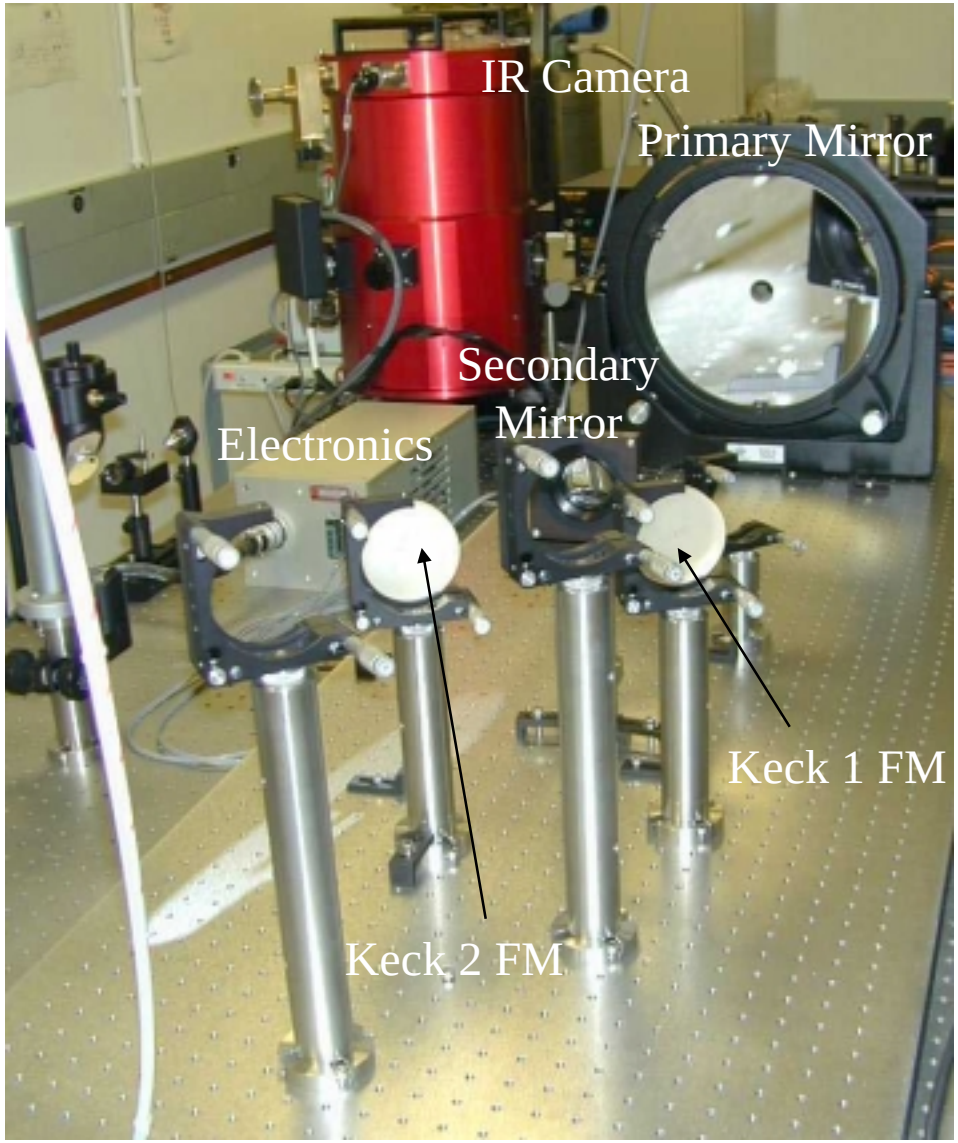
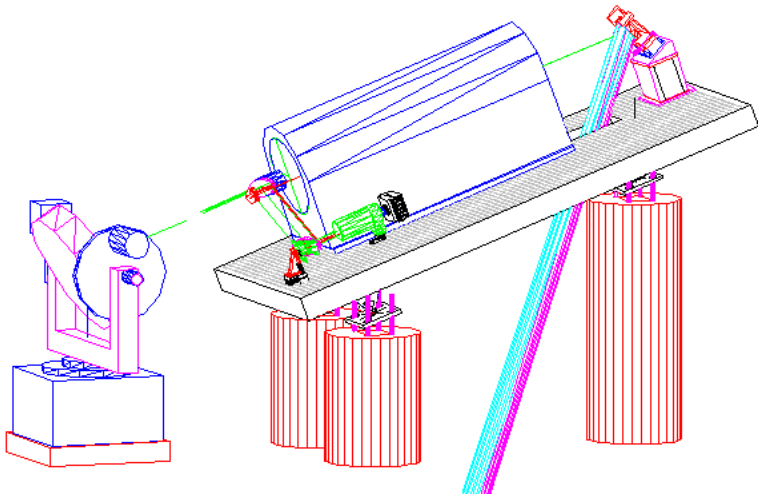
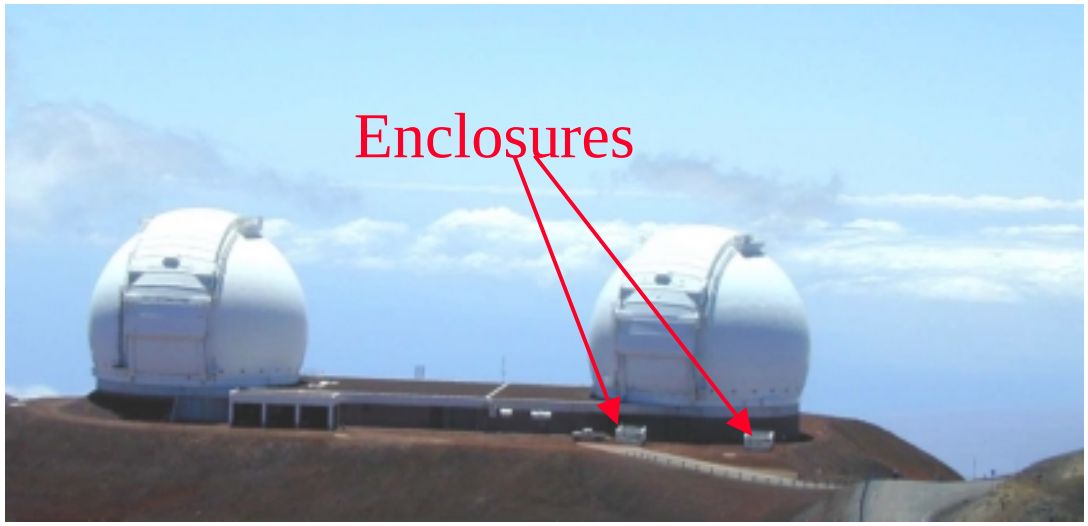


First Siderostat Fringes

- Initial fringes using the siderostats were obtained on Feb. 22, 2001
  - Checked out hardware to be used with Kecks on next run
- Instrument configuration
  - Two 50-cm siderostats feeding fixed 40 cm telescopes (essentially the same as the PTI front-end optics)
  - Angle tracking at H band controlling fast steering mirrors behind telescopes
  - 10 cm compressed beam routed to beam combining lab
  - Remaining configuration like for Kecks





Light flow for first fringes

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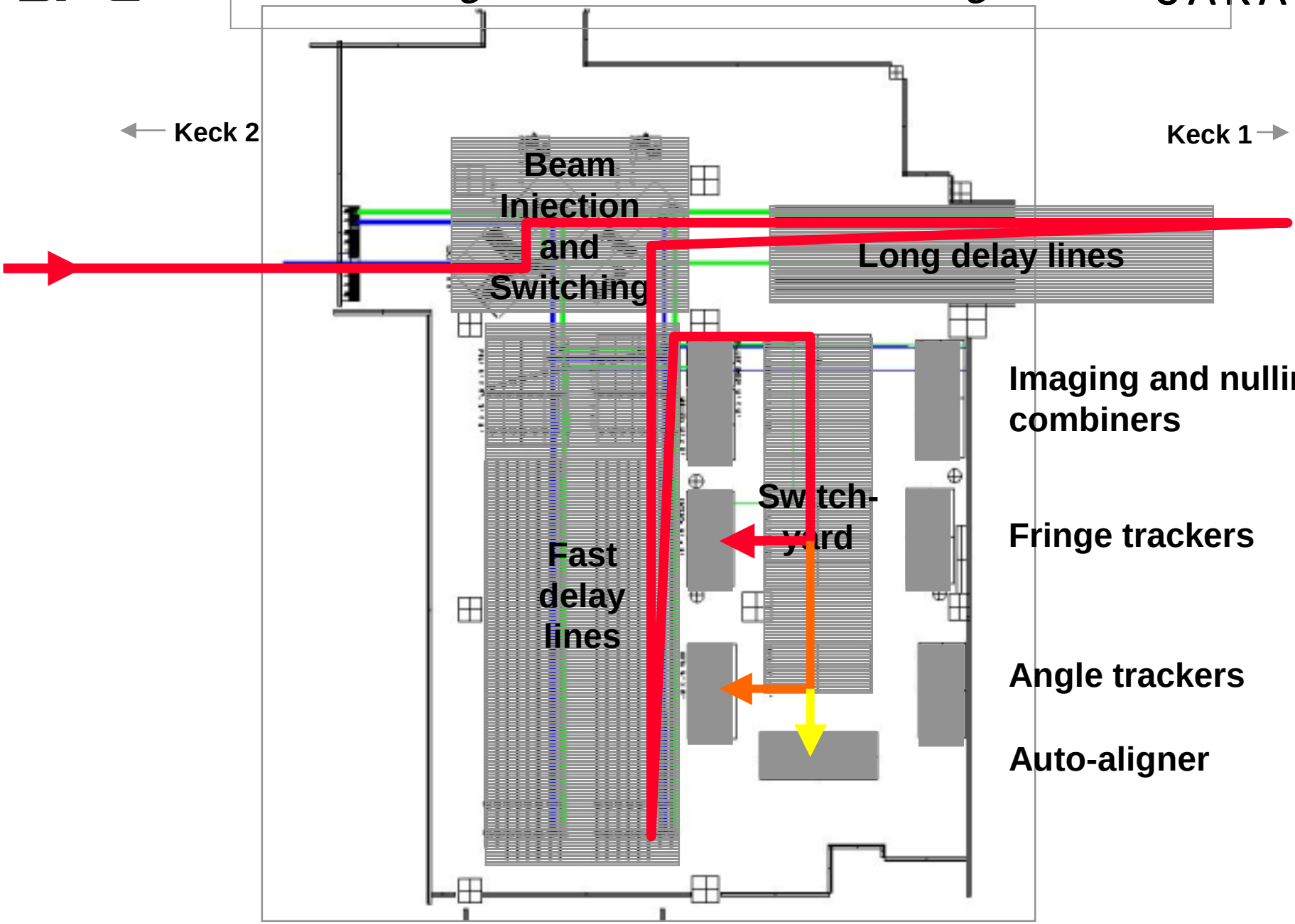

First Keck-Keck Fringes

- March engineering run: 3 1/2-nights on the two Kecks March 12-14, 2001
- Instrument configuration
  - Two 10 m Kecks feeding interferometer via coude optics
  - Natural guide star adaptive optics running on both telescopes using R and I light
  - Slow guiding corrections from interferometer angle tracker at H band to AO system
  - Fringe detection at K band using interferometer fringe camera
    - » Synchronous demodulation (a.k.a. fringe scanning) at 1 kHz frame rate
    - » Single broadband K channel
  - Laser controlled fast delay lines

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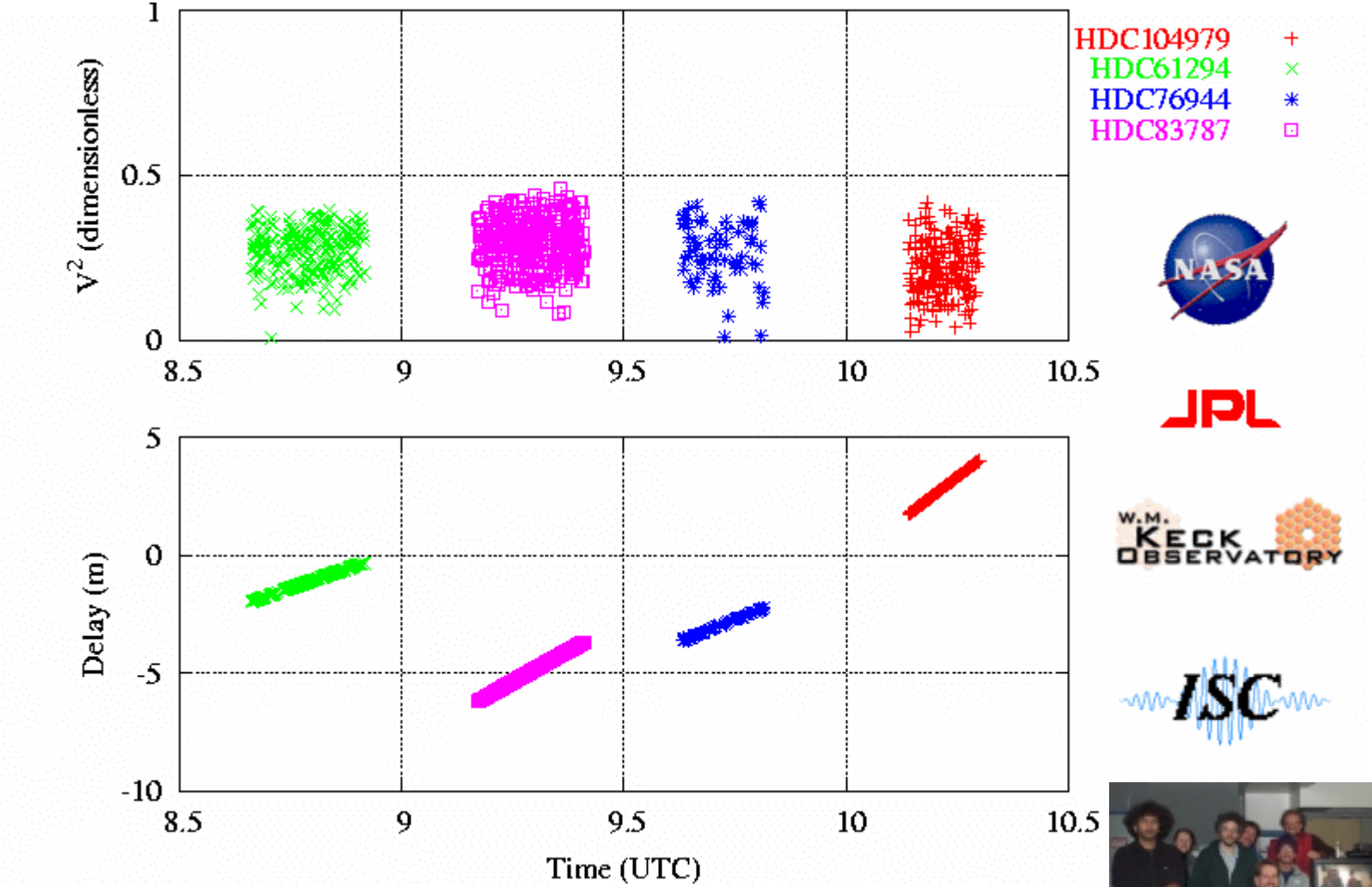
First fringes, March 12, 2001



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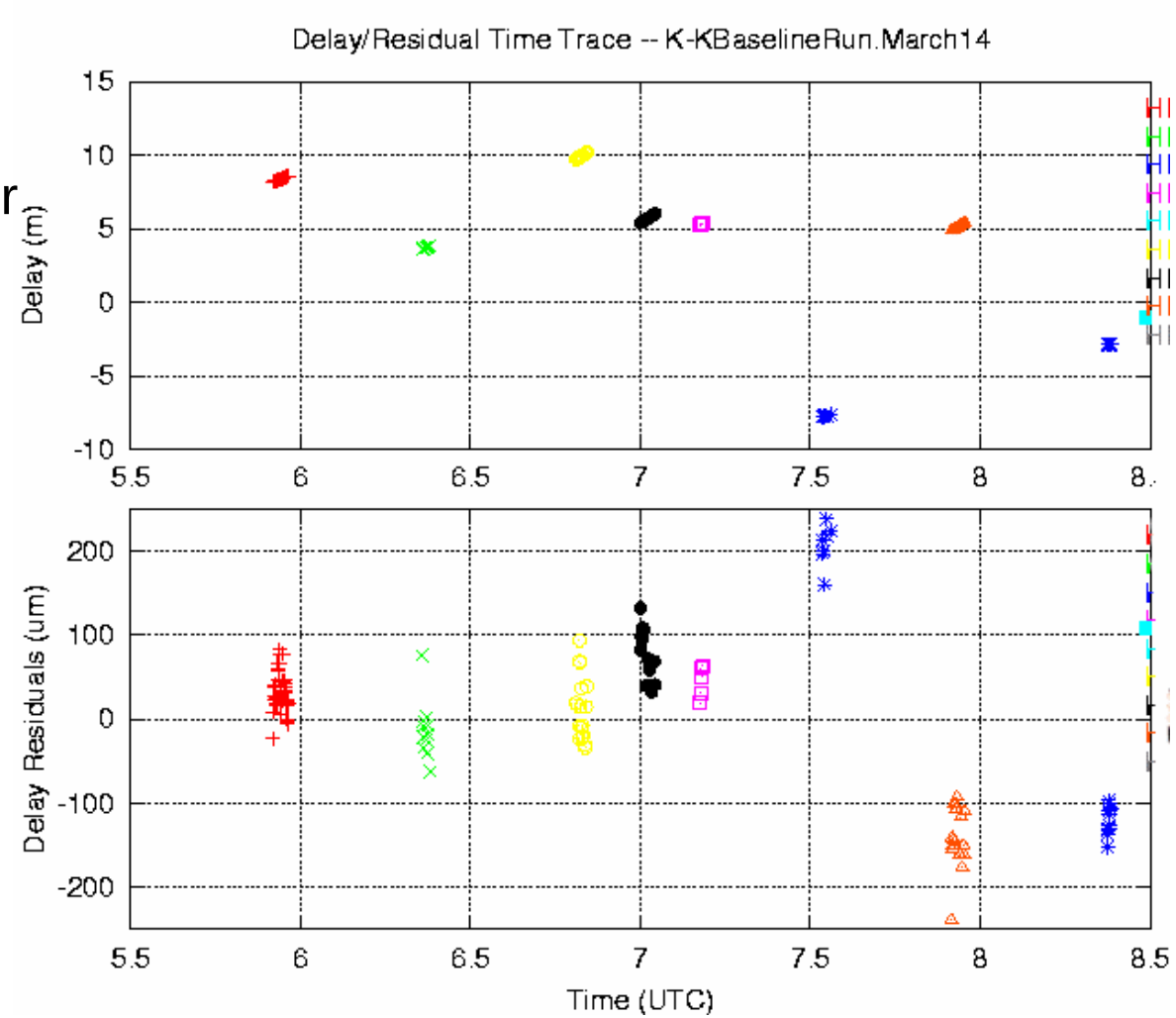
Keck-Keck Baseline Stability

- Test on March 14
- 9 stars used to solve for Keck-Keck baseline using a priori star positions
- Delay range: +/- 10m (fixed LDL) position
- Delay residuals after solution
  - ~100 λm rms using ideal pivot model



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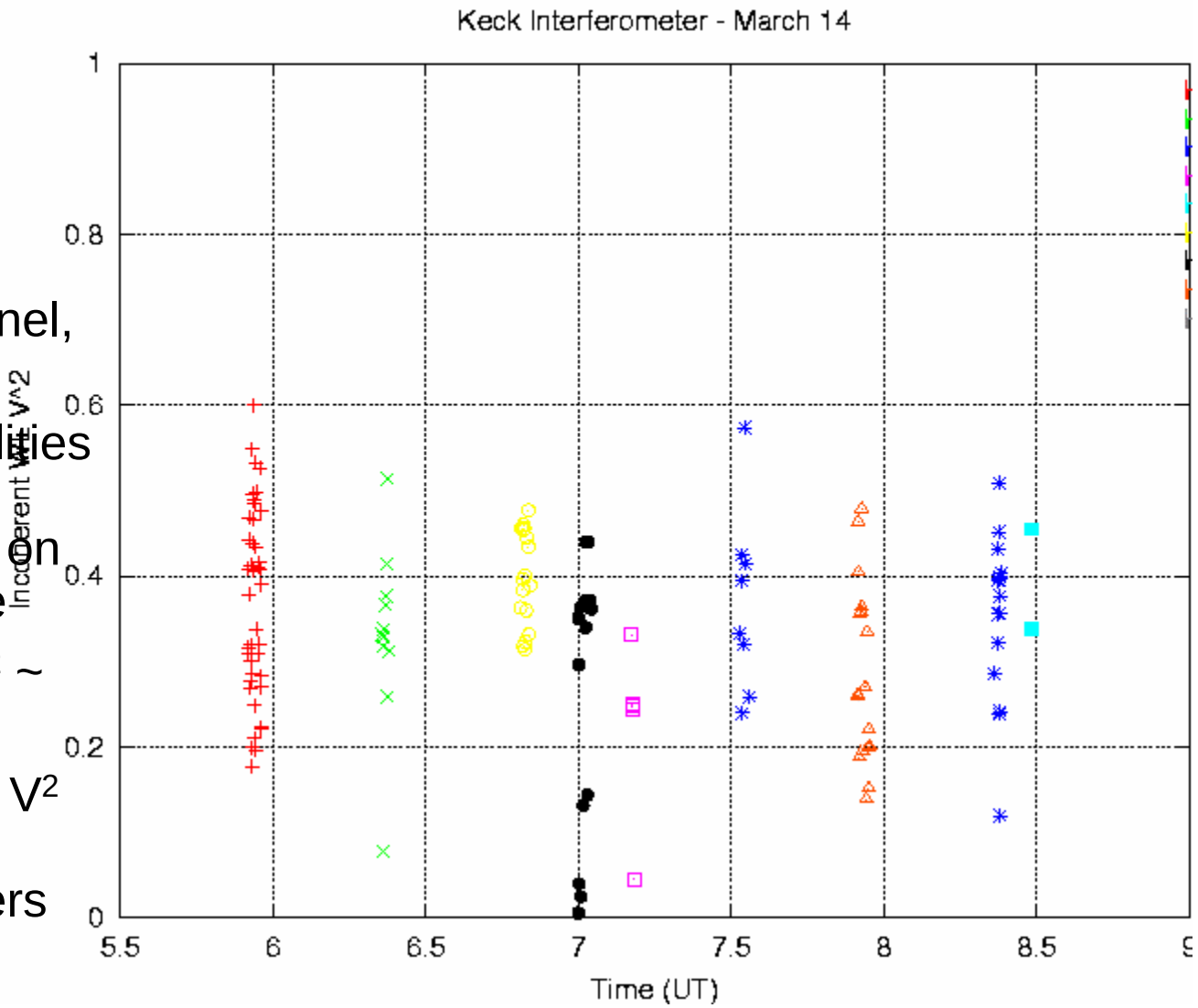
System Visibility

- Test on March 14
- Integrated with baseline tests
- Test used a single broadband K channel, no fringe centering
  - Range of visibilities correspond to different points on fringe envelope
- Peak measured V^2 ~ 55%
  - Implies system V^2 of ~75% given source diameters



Near-Term Activities

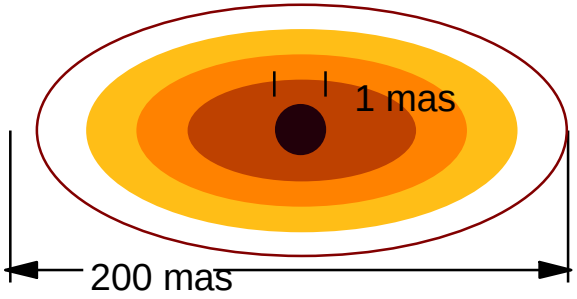
- Preparation for routine V^2 observations
  - Vibration amelioration to allow longer coherent integration times
    - » Stiffening optical tables, damping mounts
    - » Isolating equipment
    - » End-to-end laser monitored pathlength compensation (originally planned for later in project)
    - » End-to-end laser monitored tilt compensation (new)
      - Both prototyped in June engineering run
  - Upgraded fringe camera to provide broadband + spectral channels
  - Next increments of real-time and supervisory software
  - System characterization (V^2 stability, etc.)
  - More automation and sequencing for improved ease of use
- (Commissioning Team Science NRA closed June 29)

Intermediate-Term Activities

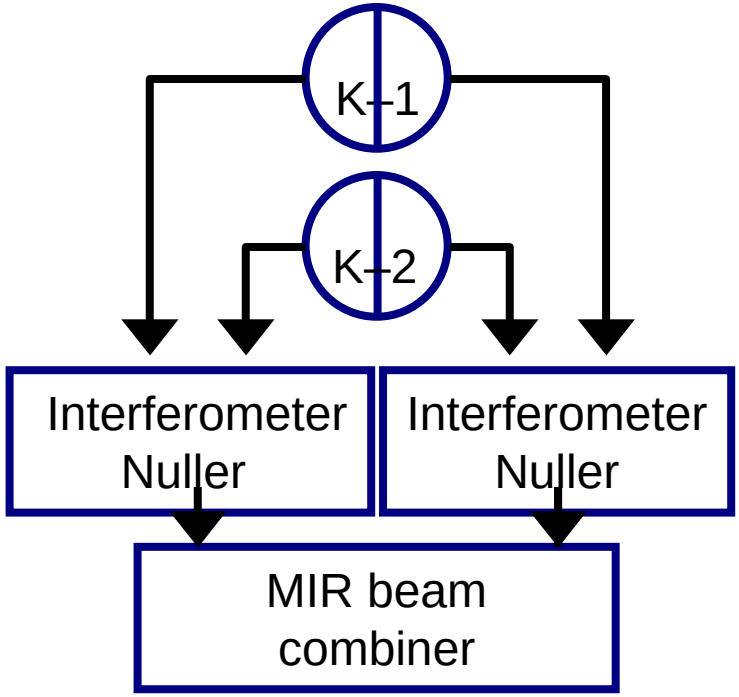
- Preparations for nulling and differential phase
- For nulling
  - Add more delay lines, transport optics, metrology, etc. to implement shared-aperture scheme
  - Add nulling front end and 10-λm camera
  - Integrate and validate
- For differential phase
  - Add vacuum delay line for precise atmospheric compensation
  - Add 2-5 λm fringe-tracker camera and high precision fringe demodulator
  - Integrate and validate

Detection of Exo-zodiacal Dust Around Nearby Stars

- Target accuracy: < 10 solar-system equivalents
- Approach: multi-baseline nulling at 10 λm
  - Send two beams to basement from each telescope
  - Null star on each of two K1-K2 baselines
  - Interfere nulled outputs with two-way combiner

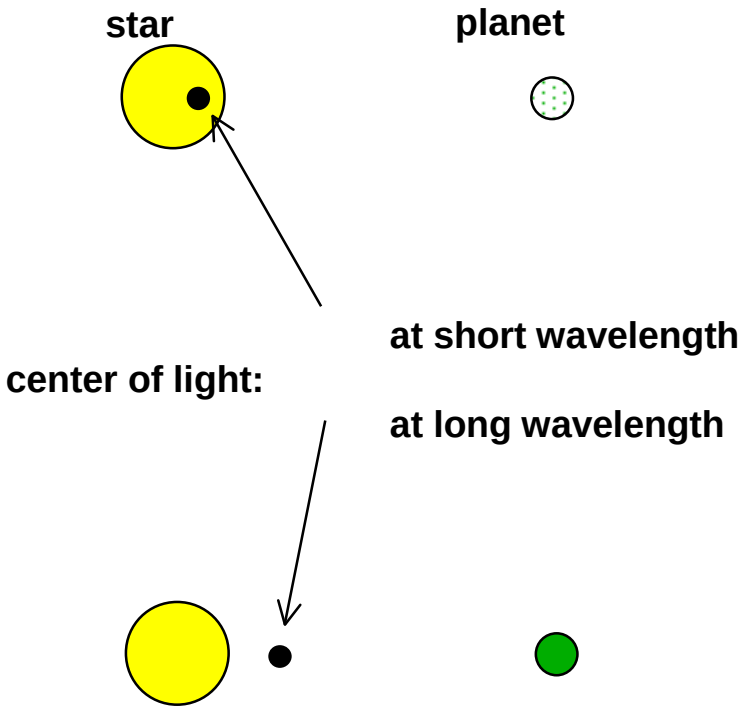


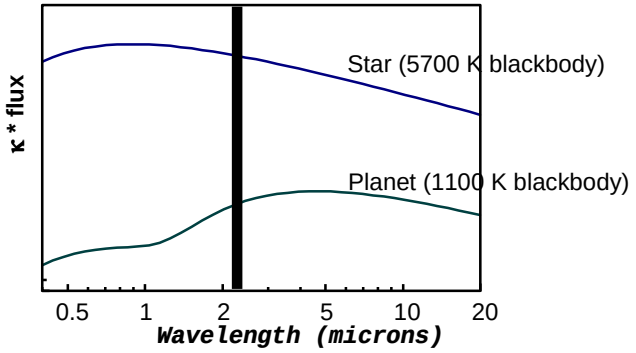
1AU radius disk at 10 pc

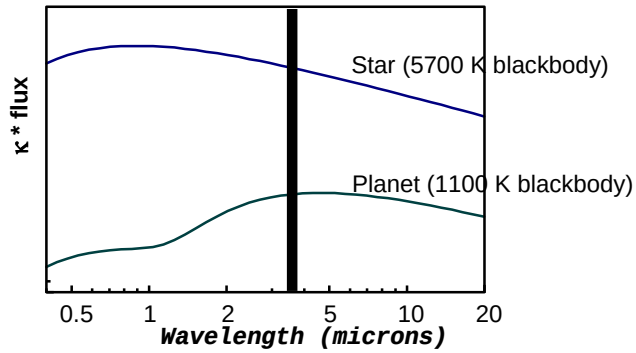


Detection of Hot Jupiters

- Use differential phase technique to directly detect extra-solar planets and stellar companions via wavelength dependence of system fringe position
- Target accuracy: 51 Peg signature







(approximation for star-planet separation << fringe spacing)

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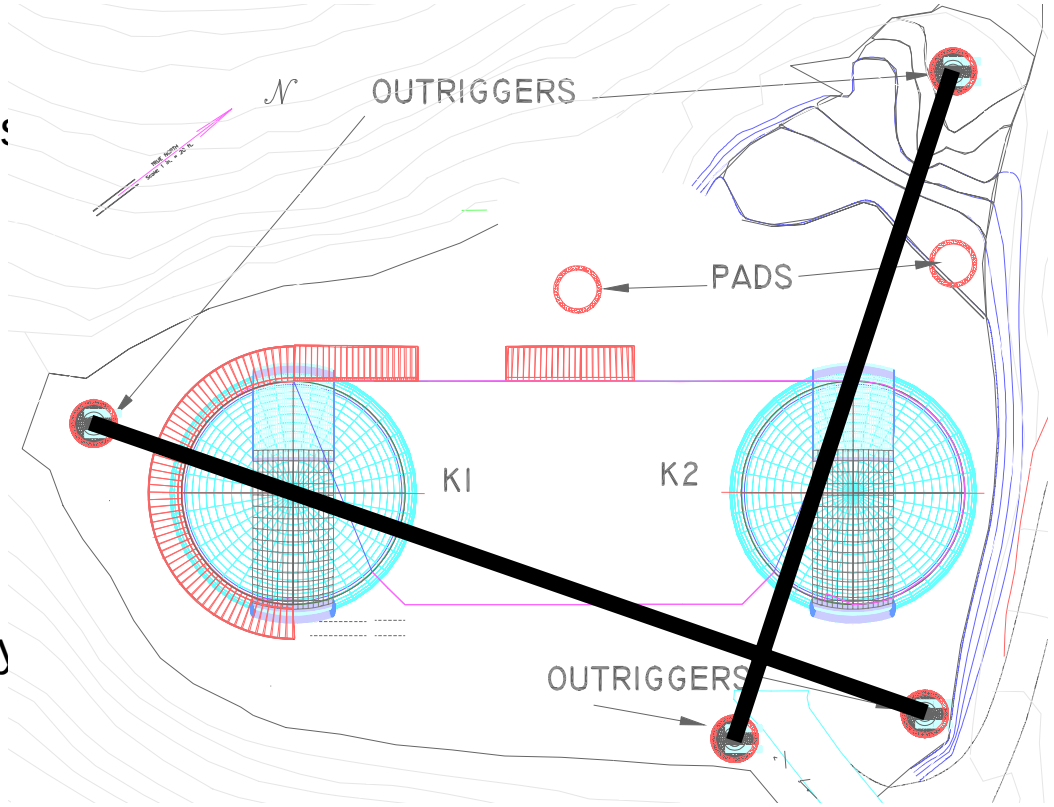
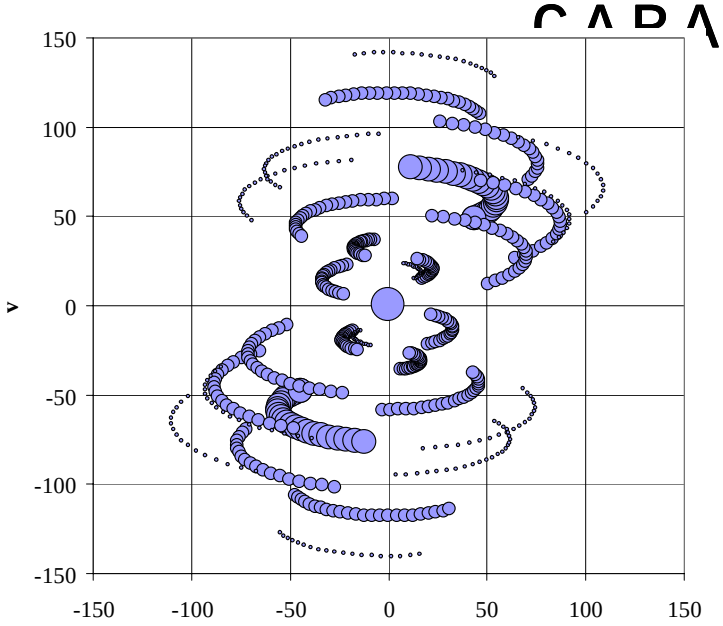
Astrometric Search for Planets to Uranus Mass

- Configuration
  - Four 1.8 m outrigger telescopes
  - Two 100 m baselines
  - 30 λas•sqrt(hr) accuracy for differential astrometry
  - Details
    - » Cophased interferometer architecture at 2.2 λm
    - » Dual star feeds
    - » End-to-end laser metrology



Imaging

- Imaging with 6-element array
- 9 of 15 baselines include a 10-m telescope
  - Background-limited sensitivity equivalent to two 4.4-m's
- 2-5 λm imaging detector
- Sensitivity: K=19 (point source, 1000 s, K-OT baseline)



u,v coverage with outriggers and Kecks
(width of line indicates baseline)